In-Space Transportation Capability Roadmap Development

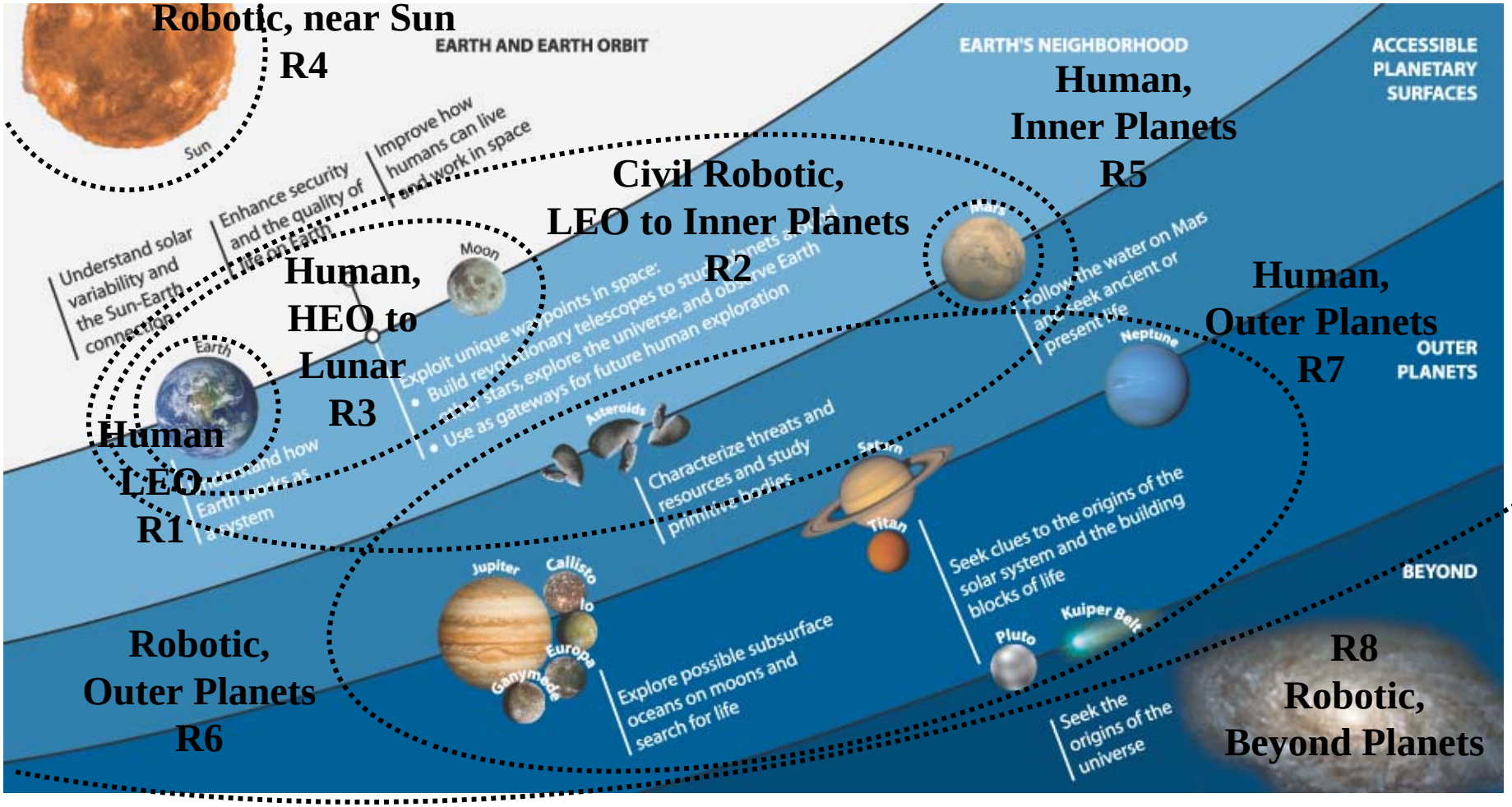
IST CRM Team Presentation
APIO Open Forum
November 30, 2004

Summary

- **Develop the capability roadmaps for In-space Transportation that are required to support the Vision for Exploration**
  - Orbit-to-orbit transportation
  - Any necessary in-space transfer
  - Includes
    - Potential synergy with upper stage
    - Descent propulsion
    - Planetary ascent
  - Special emphasis on:
    - In-space main engine
    - Cryofluid management
    - AR&D
    - Aerocapture, solar sails, low power EP
- **Planning treats capabilities as elements/stages of a system**
- **Planning must be consistent with the Exploration spirals and science mission schedules**

Relevance - Regimes Based on Common In-space Transportation Capability Requirements

Stepping Stones Overlay on Space Transportation Regimes



In-Space Transportation is a fundamental capability required to enable all aspects of Exploration Vision

In-Space Transportation Capability Roadmap Team

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♦ Col. Joe Boyle	USAF/SMC (co-chair)
♦ Mr. Pete Vrotsos	NASA/HQ
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♦ Dr. Tim Crain	NASA/JSC
♦ Mr. Mike Meyer	NASA/GRC
♦ Dr. Russ Partch	AFRL/VSE
♦ Mr. Alan Sutton	AFRL/PRSE
♦ Mr. Ron Reeve	NASA/JPL
♦ Dr. Ted Johnson	NASA/LaRC
♦ Dr. Jesse Leitner	NASA/GSFC
♦ Dr. Shamim Rahman	NASA/SSC

Consulting/Eng.Support

♦ Ms. Carol Covell	MSFC/Jacobs Eng.
♦ Mr. Brand Griffin	MSFC/Gray Research

Independent reviews/consulting

- ♦ Periodic review by Academic Experts review team
- ♦ Periodic review by Industry Experts review team

In-space Transportation Capability Assessment
Capability Breakdown Structure

Top Level CBS Structure

1.0 In-Space Transportation Elements

2.0 Human Exploration Mission Elements

- 2.1 Crew Launch Vehicle Upper Stage
- 2.2 Cargo Launch Vehicle Upper Stage
- 2.3 Earth Departure Stage
- 2.4 CEV Service Module
- 2.5 Extra Planetary Lander Stage
- 2.6 Extra Planetary Ascent Stage

3.0 Robotic Science and Exploration Mission Elements

- 3.1 Robotic Space Craft Earth Departure Stage
- 3.2 Robotic Space Craft Extra Planetary Capture Stage
- 3.3 Robotic Space Craft Extra Planetary Lander Stage
- 3.4 Robotic Space Craft Extra Planetary Ascent Stage
- 3.5 Robotic Space Craft Planetary Earth Return Stage

In-space Transportation Capability Assessment
Capability Breakdown Structure

CBS Structure below the element level is essentially common.

1.0 In-Space Transportation Elements

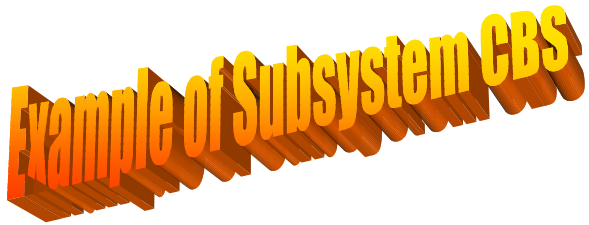
X.0 _____ Mission Elements

X.1 Element

X.1.01	Integration Structure and Components
X.1.02	GN&C
X.1.02.1	Trajectory Control Algorithms
X.1.02.2	Autonomous Rendezvous and Docking System (if applicable)
X.1.03	Structures
X.1.03.1	Propellant Tanks
X.1.03.2	Primary Structures
X.1.03.3	Secondary Structures
X.1.03.4	Deployable Landing Mechanisms (if applicable)
X.1.04	Propulsion Systems
X.1.04.1	Main Engine
X.1.04.2	Attitude / Reaction Control System
X.1.04.3	Main Propulsion System
X.1.04.4	Propellant Pressurization System
X.1.04.5	Orbital Maneuvering System (if applicable)
X.1.05	Thermal Systems
X.1.05.1	Cryo-fluid Management System
X.1.05.2	TPS
X.1.06	Avionics
X.1.06.1	Integrated Health Management System
X.1.06.2	Control System Hardware and Software
X.1.06.3	Sensors
X.1.06.4	Power Supply
X.1.07	TVC System
X.1.07.1	Actuators
X.1.07.2	Power Supply
X.1.08	Docking and Separation Systems
X.1.08.1	Docking Adapter
X.1.08.2	Separation Motors

In-space Transportation Capability Assessment Capability Breakdown Structure (e.g. GN&C/AR&D)

CBS Structure below the subsystem level



- **Guidance**
  - Real-time Guidance Algorithms
    - Guidance laws and algorithms
    - Sensors
  - Targeting and Trajectory Design
    - Targeting algorithms
    - Vehicle health/status information
    - Navigation knowledge requirement insight
- **Navigation and Attitude Determination**
  - Absolute
    - Sensors
    - Algorithms
    - In-space infrastructure
  - Relative
    - Sensos
    - Algorithms
    - Chaser-target infrastructure
- **Control**
  - Actuators
    - Propulsion systems
    - Mechanical devices
  - Algorithms for Actuator Control
    - On-orbit attitude control (RCS/momentum exchange)
    - Attitude control with aero (RCS/aerosurfaces)
    - Gross propulsion system control
- **Simulation Tools**
- **Autonomy and Automation Tools and Algorithms**

Subteams for planning

- Chemical propulsion
- Non-chemical propulsion
- Structures
- GN&C, AR&D
- Docking and Separation Systems
- Thermal systems
- Avionics
- TVC Systems

In-Space Transportation CRM Team Plan/Approach

- **Previous and current studies reviewed for applicability**
  - CRAI
  - 120-day Study
  - SLI Planning studies and technology maturation results
  - HR&T, intramural, and extramural awards
  - IISTP
  - Available architecture studies
- **Review of requirements**
  - DRM's, DRA's, Framework, ConOps
    - ESMD missions
    - Science missions
    - Framework matrix generated by ESMD/APIO
- **WBS/CBS structure by which to build planning activities**
  - Content will be under configuration control
- **Roadmap planning activities by team**
  - Mapping of previous study results to WBS/CBS
  - Gap identification/analysis/fill-in
  - Roadmaps, subsystem roadmaps, supporting quad charts
- **Plan to TRL6+, integrate into spiral schedules and science regimes**
- **First draft presentation to the Academy in the middle of February**

In-Space Transportation CRM Team Plan/Approach

- Review/advising by academic review team
- Review/advising by industry review team
- Review by National Academy of Engineering
- Update roadmap plan per recommendations of reviews
- Align roadmaps with strategic roadmaps/plans
- Final review with National Academy of Engineering
- Final roadmap plan to be delivered in August

Status

- Team kick-off meeting on October 12
- Team telecons twice a week
- CBS developed and integrated with other CRM teams
- Academic review team formed
- Started mapping previous study results to CBS
- Developing subsystem CBS's
- Planning for independent reviews

Points of Interest

- Another team is planning for nuclear propulsion and power
- Other teams are responsible for entry
- Fundamental intelligence algorithms is on another team
- Modeling and simulation is on another team
- Human-carrying elements are on another team
- Our emphasis is on the in-space transportation and integration into the hardware development

Summary of White Papers

- **Thirty-eight papers submitted related to In-space Transportation**

- **Grouped into nine categories**
  - AR&D 5
  - Avionics 1
  - CFM 6
  - Chemical Propulsion 9
  - IST Architecture Elements 5
  - Non-Chemical Propulsion 3
  - Propellant Transfer 1
  - Structures 5
  - Test Facilities 3